

LI. *On the Aquiferous and Oviducal System in the Lamellibranchiate Mollusks.* By GEORGE ROLLESTON, Esq., M.D., F.L.S., Linacre Professor of Anatomy; and C. ROBERTSON, Esq., Demonstrator of Anatomy, Oxford*.

VERY different explanations have been offered of the means by which certain of the Lamellibranchiata are enabled to distend their muscular foot until the fluid with which it is swollen up causes it to appear all but transparent. These explanations, different as they are both in principle and in detail, admit yet of being reduced under one or other of three heads. Either they postulate the existence of a system of tubes homologous with the tracheæ of insects, and, like them, distinct from the animal's blood-vessels, as necessary for the explanation of the great changes of volume observed to take place in the mollusk's body; or they suppose these alterations of size to be effected by the agency of the blood-vascular system alone; or, thirdly, they hold the effect in question to be due to the joint working of these two systems of tubes.

Agassiz† refers the great distention observable in the foot of the *Natica heros*, of the *Pyrula carica* and *canaliculata*, and the Acephalous *Mactra solidissima*, to water inhaled by orifices more or less numerous, of less or greater calibre, in the muscular foot: these orifices, and the tubes in connexion with them, he speaks of as a water-vascular system, but he holds that they come into more or less direct and constant communication with the true blood-vascular system.

Theodor von Hessling‡, who obtained the same result of injecting fully the blood-vascular system, by throwing in fluid from the glandular depression in the foot of the *Unio margaritifera*, as Agassiz did by a similar procedure with the similar depression in the foot of the Gasteropodous *Pyrulæ*, speaks of the system (which on these grounds he holds to be continuous) as but one system and that a blood-vascular system, with certain orifices patent and communicating with the external medium in which the animal lives. Von Hessling holds also that the distention of the foot may be in part due to water inhaled through the organ of Bojanus, and mingled thus with the blood, as we shall presently describe.

M. Langer§ holds that the organ of Bojanus is the route by which the water, upon which the change of volume in the animal's body depends, passes into it, and that this water passes into the blood-vessels, and not into any specialized water-vascular system.

* From the Philosophical Transactions, Part I. for 1862, p. 29.

† Zeitschrift für wiss. Zoologie, Pt. 7. p. 176, 1855.

‡ Perlmuscheln und ihre Perlen. Leipzig, 1859: p. 241.

§ Denkschriften d. Kaiserlich. Akad. Wiss. xii. p. 55, 1856.

M. Lacaze-Duthiers has discovered and described* yet another route than that of the organ of Bojanus, by which, in the *Dentalium* and *Pleurobranchus*, water from without can find its way into the interior of vessels carrying blood, and carrying it in these instances towards the heart, and not towards the gills.

Gegenbaur† differs from these authors merely in postulating the existence of orifices of exit as well as of entrance for the water; and these he holds to correspond with the puncta scattered over the foot-surface, and visible in great abundance occasionally along and near its free edge.

Von Rengarten‡ exactly reverses the functions thus supposed to belong to the punctated foot-pores, and the passage through the organ of Bojanus severally.

In a paper read by us§ before the Royal Society, February 3, 1859, we spoke of the water-vascular system as having its outlet in close approximation to the external orifice of the organ of Bojanus; and its inlet we suggested might be indicated by the position of the parasites which are not rarely to be seen studding the foot-surface and marking out the presence of its numerous pores. Gegenbaur, we observe||, considers that the great liability of the foot to injury from the entrance of foreign bodies into these pores is an argument for regarding them as exhalant rather than inhalant orifices.

Further investigations, carried on by us subsequently to the reading of that paper, showed us that our views as to the oviducal system in the Lamellibranchiata were founded in error. An exceedingly courteous notice of this mistake by M. Lacaze-Duthiers¶ in the 'Proceedings of the Royal Society' rendered an earlier retraction of this part of our paper unnecessary. Our views, on the other hand, as to the permeation of the bodies of the Lamellibranchiata by a system of vessels distinct from those in which the blood is contained remain much what they were.

Before stating our views, and the arguments by which we would support them, we would say that the "perivisceral chamber" of the Brachiopoda, as described by Mr. Hancock** in a paper in the 'Philosophical Transactions,' which was published subsequently to the reading of our paper already referred to, holds much the same relation to the circulatory and reproductive and other viscera, as the system which we have called "aquiferous" in the Lamellibranchiata. As Mr. Hancock†† has

* Ann. des Sciences Naturelles, tom. xi. 1859, p. 255; Ann. Nat. Hist. ser. 3. vol. v. p. 225.

† Grundzüge der vergleichenden Anatomie, p. 352, 1859.

‡ Diss. Inaug. Dorpat, 1853, cit. Von Hessling, *loc. cit.* p. 236.

§ Ann. Nat. Hist., ser. 3. vol. iv. p. 65.

|| *Loc. cit.* p. 352.

¶ Ann. Nat. Hist., ser. 3. vol. v. p. 225.

** Philosophical Transactions for 1858. Read May 14, 1857.

†† *Loc. cit.* p. 844.

himself pointed out the close correspondences of the two systems, we will but remark upon one point of discrepancy between them. In the Brachiopods the genitalia are packed into the main stems of the arborescent perivisceral system, in the direct course of the stream, if we may speak of it as a water-vascular system; in the Lamellibranchiata, or, at all events, in the family Unionidæ, the cæca of the generative gland are appended laterally to the divergent twigs of the principal branches of the water-vascular tree; they do not lie in the direct course of the current of the aquiferous canals, and these canals, beyond and outside of them, break up into a very delicate minutely divided system of capillary tubes. What we shall attempt to prove is, that the orifices on either side of the foot in the Unionidæ lead not only to the generative gland, the products of which may be seen to issue forth from them at the spawning-season, but also to a system of tubes widely spread through the entire foot. We do not believe that any direct communication subsists either between the blood-vascular system and this system of tubes, or between either of these systems and the punctated depressions and inlets along the foot-edge. The blood-vessels seem to us to constitute a system of tubes closed, save at one point and at one lacuna. That point and that lacuna is the pericardial space—a cavity into which, besides the blood of the animal, the water in which it lives also finds its way. As the bivalve shell opens, it necessarily dilates this lacuna, and water is thus drawn into it through the compound sac known in the Acephala as the organ of Bojanus. The water then gains access to the interior of the blood-vessels, as we shall proceed to show, and is carried onward within them. From the blood-vessels we suppose it to transude into the system of water-tubes everywhere in apposition with them, and, under normal conditions, to find its exit by these tubes, whilst under such abnormal circumstances as the sudden removal of the creature from the water, the sudden contraction of the muscular foot, causing jets of water to pour forth from the dilated semitransparent mass, may unload the infiltrated organ in a yet more expeditious manner. As to the way by which the water used by the mollusk for distending its foot comes into the body, we are at one with many other writers upon this subject; but we are not aware that our views as to the method by which the animal disencumbers itself of the ingested fluid are shared in by other authors.

Our arguments will be principally based upon the results of experiments made in the way of injection. The animals we operated upon were almost exclusively of the family Unionidæ; and, on account of the size of the specimens, as well as for other reasons, we employed chiefly the species *Anodon cygneus* and *Unio margaritifera*. In all our experiments we strove to reproduce, as nearly as possible, the conditions of the animal's na-

tural life: our injections were always performed under water, by which and by other means as much support was given to the animal's body and its several parts as the water and the shell gave to it during life. Means were always adopted for securing that the animal died with its muscular system in a state of relaxation. We found the prussian blue injecting-fluid of Prof. Beale's* invention to possess many properties especially recommending it for use in our experiments, but we employed several other fluids as well.

Experiment 1.—If an *Anodon* or *Unio* (size is of little consequence in this experiment, though large size is a convenience in most) be removed from its shell without injuring the somewhat easily injured tissues which limit the secreting-structure of the organ of Bojanus, and supported in water with its foot downwards in such a manner as to put its pericardial lacuna, and the parts in connexion with it, as nearly as possible into the condition in which they may be supposed to be in in the shell during life, and if an injection be then made into the pericardial lacuna, the following results will be seen to take place. The so-called "reddish-brown organ of Keber" (a plexus of vessels rich in pigmentary deposit, continuous with other vessels not so coloured in the mantle and elsewhere, and bounding the pericardium on either side, and opening into it by several patent orifices at its anterior end) will become filled with the injecting-fluid first; next the gill-vessels, and sometimes together with them, yet not invariably, the systemic veins; and lastly the external orifice of the organ of Bojanus will, on removing the animal from its prone position, be seen pouring out the injection on either side of the animal's foot.

Experiment 2.—A large *Anodon* was injected with a red stiffening-injection from the central branchial vein, a vessel readily injectible, lying as it does in the gill-cavity superiorly between the two innermost laminae of the gills, in the angle where they become continuous with each other posteriorly to the posterior edge of the foot, with the following results:—The auricle and ventricle were filled to distention, the reddish-brown organ as well, and, besides the reddish-brown organ, the rest of the mantle, up to within a quarter of inch of its free edge. No fluid, however, had penetrated into the pericardial space. The absence of penetration into the pericardium we have invariably had to record in our numerous injections from the branchial veins, even when the injection is noted as having been so entirely successful as to have passed through the aorta in such abundance as to inject in fine ramuscular divisions the edge of the muscular foot.

* 'How to work with the Microscope,' p. 78, 1857.
Ann. & Mag. N. Hist. Ser. 3. Vol. x. 30

The former of these two experiments is so easy of performance, and yet proves so much, that we cannot but express our surprise at nowhere finding any record of its having been made by any of the different experimenters who have employed injections as a method for investigating the economy of mollusks. We have repeated it so frequently with the same results, as to have become quite convinced that the pericardial lacuna communicates, on the one hand, with blood going gillward, and, on the other, with the water in which the animal lies.

The uniformity with which our repetitions of Experiment 2 have led to the same negative result inclines us to doubt the existence of any direct communication between the aquiferous pericardial lacuna and the branchial veins properly so called. We are the more disposed to accept this conclusion, as in no mollusk whatever which is possessed of branchial vessels, except the *Pleurobranchus**, has the renal organ been shown to conduct the external water into the cavity of vessels homologous, not with the afferent, but with the efferent † branchial vessels of higher organisms.

Though Experiment 2 may seem to prove that the intravascular blood does not set in any very free current outwards into the pericardial space, especially when coupled with the observation that in multitudinous and varied injections of the different systems of blood-vessels we have never succeeded ‡ in filling the pericardium from the blood-vessels, easy though it be, as in Experiment 1, to make the injected fluid take the reverse direction, more direct evidence is yet needed in support of our view of the organ of Bojanus as the channel for an inwardly-setting current of water. The following considerations seem to us to show conclusively that, though Experiment 1 shows that it is possible for intrapericardial fluid to find its way outwards through the renal organ, such is not the direction usually taken by the fluid contained in the complex aquiferous system thus constituted.

1st. If we examine with the microscope the fluid contained in the pericardial space, we shall find it to contain, besides the morphological elements of blood, certain foreign bodies, such as the *Aspidogaster conchicola* and infusoria. Now these creatures must be supposed to have found their way inwards through the organ of Bojanus.

* M. Lacaze-Duthiers, Ann. Nat. Hist., *loc. cit.*

† Gegenbaur, Grundzüge, p. 367.

‡ M. Langer's language (Denkschriften d. Akad. Wiss. *loc. cit.* p. 43), in describing his success in such injections, is so qualified, "und sah, doch nicht immer," as to allow one, without discourtesy, to give less weight to his views on this than on most other points.

2ndly. The external orifice of the organ of Bojanus may be seen in a living *Anodon* (and, from its lying exposed in the gill-cavity, with yet greater ease in a *Unio margaritifera*) to execute movements of alternate opening and shutting, similar in character to those executed, as has been repeatedly noticed, by the analogous organ in the Pteropoda. These movements are repeated as frequently as once in every ten seconds (or oftener) in the *Unio margaritifera*; and they possess, there can be little doubt, in these as in other mollusks, the power of filling with water the cavities into which it leads.

3rdly. The glandular portion of the compound organ of Bojanus has its opening into the pericardium guarded by a funnel-shaped projection which acts as a valve looking heartwards, and offers resistance consequently to fluid passing outwards from that lacuna.

4thly (Experiment 3). Fluid thrown in by the external orifice of the organ of Bojanus, as it is either artificially, as in the *Anodon*, or naturally, as in the *Unio margaritifera*, exposed in the gill-cavity, finds its way even more easily into the pericardium than fluid thrown, as already described, into the pericardium finds its way into the gill-cavity by the reverse route. This experiment is but an imitation of what we may suppose to take place whensoever the animal by opening its valves dilates its pericardial space. As an immediate consequence of this dilatation, water is ingested into the blood-vascular system, and is forthwith applied to the purpose of distending the foot and protruding it through the opening valves.

Up to this point our views are in accordance with those adopted by several authors, though we are not aware that our method of proof has been employed by any other observers, so far as its detailed application is concerned.

We will now proceed to give our reasons for supposing that another system of tubes comes in aid of the blood-vascular system, and receives from it the fluid which that system has been the means of taking up in the manner described. Our arguments will go to show that water is transferred from the blood-vessels in the foot of the freshwater mussel to another set of vessels, the main stem of which has the additional function of outlet to the generative gland. As, however, Von Hessling* holds that the system of pores in the foot plays no inconsiderable part in the work of supplying the distending foot with water, acting in aid of, and in alliance with, the system of the organ of Bojanus, and, with Agassiz and Von Rengarten, as already cited, holds this office to be exclusively discharged by this system of pores and inlets, we will begin by stating our

* Perlmuscheln und ihre Perlen, p. 238 *et seq.*

reasons for demurring to these views, in which we ourselves at one time participated. It will be necessary to give the details of two sets of experiments, to show how we came to give up an opinion which can plead such high authorities as those we have cited for its defence.

Experiment 4.—A large *Anodon*, having died with its foot in a semidistended state, was injected from the venous sinus which receives the blood from the systemic veins and distributes it to the renal-portal system, with the prussian-blue injection already spoken of. The injection spread over the liver and over the whole of the generative gland, and the exclusively muscular part of the foot, spreading itself in especial richness along the free edge. No pressure which we subjected the foot to, when thus fully injected, caused any of the blue injection, easily and readily though it runs, to issue forth. Subsequently to this, a stiffening injection of red colour was thrown into the foot-mass from the oviducal outlets. This second injection spread itself very richly over the ovary, over the liver, and into the muscular foot, *along the free edge of which it issued in small jets without any pressure being applied.*

We will disregard, for the moment, the bearing which this experiment has upon the distinctness from the blood-vascular system of the system of tubes in the muscular foot, to which the stem opening (under the name of oviduct) into the mantle-cavity leads, and we will relate the details of another set of experiments, which led us to consider the phenomenon of the jets issuing from the foot-edge as due, in spite of the frequency with which we have seen it recur, to violence done, possibly unavoidably, to the delicate limitary tissues of these aquiferous tubes.

Experiment 5.—A *Unio margaritifera*, which had died with its foot quite relaxed, had the blue injecting-fluid introduced into its aorta, its venous system, and through the oviducal orifices, until the foot, from a state of perfect softness, became tense and swollen up. *On pressure, none of this triply-injected blue fluid could be made to issue forth from the foot-edge; but small hernia-like projections of transparent membrane rose out like bubbles all along the foot-edge.* They contained at first a transparent fluid, but after a little pressure they became filled with the blue injection. The thinness and transparency of these little sacs will account for the rarity of their appearance, and the comparative frequency with which jets of injected fluid have made themselves noticed in the region corresponding to the cæcal endings of tubes which these sacs must be held to represent. The depressions and pores which do exist in the foot of the Lamellibranchiate mollusk we believe to be glandular in character, and destitute of any direct communication with the

blood-vessels or other tubes in the animal's body. Now the *Unio margaritifera* stands in the same relation with reference to these foot-pores to the *Anodonta cygnea* as the *Pyrula carica* and *P. canaliculata* do, according to Agassiz, to the *Maetra*; that is to say, the foot of the *Unio* presents us with a gigantic pore, in the shape of a glandular depression of as much as an inch in length and two lines in diameter, whilst that of the *Anodon* is pierced but by microscopic inlets. Von Hessling*, by whom this organ has been very accurately described, believes that injections can be made to pass, without rupture of any limiting membrane, from its cavity into the blood-vessels; and Agassiz holds a similar view with reference to the nearly similar structure in the *Pyrula*. But in the *Unio* just spoken of as so fully injected, as well as in several others similarly treated, though the sides and walls of this glandular depression were very richly injected, none of the injection could by pressure be made to issue out into the water in which the animal was lying. We should be inclined to consider this involution or glandular depression in the foot of the *Unio* as homologous with the foot-gland of the terrestrial Gasteropods; and the communication which has been held to exist between this Lamellibranchiate organ and its vascular system we should not believe to be more direct than that which subsists between the muciparous foot-gland of the *Limax* and its venous system †.

It is not quite beside the purpose, to remark that the foot of one of the Unionidæ, when thoroughly distended, has a smooth bright appearance, so uniformly spread over the whole surface of its semigelatinous mass as to suggest the idea of the depressions having become everted and thus contributed to increase the size of the infiltrated organism. Though this appearance may not justify such an interpretation, yet it does seem quite inconsistent with the existence of patent pores communicating with the animal's blood-vessels.

We have repeatedly observed that, if a freshwater mussel die with its muscular foot in a state of contraction, no distention of the foot takes place, either by leaving the animal to soak in water till putrefaction sets in, or by artificial injection.

We will now proceed to state our reasons for holding the existence of a water-vascular system distinct from the blood-vessels of the Lamellibranchiata. Siebold ‡ states one of the objections urged against the existence of this system of vessels in the fol-

* *Loc. cit.* p. 238. Von Hessling, however, does not mention the occurrence of calcareous concretions impacted in this gland's duct. This we have observed.

† Siebold, *Anatomy of Invertebrata*, p. 255, note 6, American edition.

‡ *Ibid.* p. 213.

lowing words:—"The existence in these animals of a double system of lacunæ having this interpretation is attended with many difficulties. For then it must be admitted that one of these systems contains only water and the other blood, and it is difficult to understand how two kinds of wall-less canals can traverse the body without passing into each other." It is, however, demonstrable that in the Unionidæ, at all events, an all but perfectly closed system of blood-vessels exists. We have again and again, with various injecting fluids, found that they will pass from the aorta through a capillary system into a systemic-venous system, from that into what may be called the renal-portal system of the organ of Bojanus, and from that into the branchiæ, without any extravasation, or the formation of any lacuna anywhere. The pericardial space is, in the strictest sense of the phrase, a blood-lacuna; but, as already detailed, fluid cannot be made to pass into it from the blood-vessels, though such communication must take place to a certain extent during the life of the animal, and though the reverse direction of current is one easily demonstrable by artificial means, and is doubtless the ordinary one under normal conditions. There are two venous sinuses, however, in the Unionidæ, receiving, one after the other, the systemic-venous blood, and transmitting it into the organ of Bojanus. The first of these* lies just within the muscular foot, along its superior and posterior edge; it subtends the second, the only one mentioned by authors, and opens into it by an orifice more or less perfectly guarded in different species of Unionidæ. This second sinus lies between the two opposed organs of Bojanus; and from it the systemic-venous blood passes into the capillaries of the renal-portal system contained in those organs. But neither of these sinuses at all answers the character intended to be expressed by the term lacuna; they are homologous rather with the dilated great veins of certain vertebrata than with the lacunæ which do exist in certain molluscan families. There is the less occasion, however, to labour further at demonstrating the non-lacunar character of the blood-vascular system of the Unionidæ, as Von Hessling†, in his recent book on the Pearl Mussel, confirms in this

* Into this sinus the cæca of the generative gland project somewhat freely from amongst the trabeculæ which run across what we call the roof of the muscular foot, from one side to the other; and it is here, we believe, that in injections from the oviducal outlets extravasation so often takes place into the blood-vessels.

† *Loc. cit.* p. 219. Gegenbaur, in his 'Grundzüge,' p. 344, note, hints at some doubt still remaining in his mind as to the distinctness of these capillaries from the tissues they lie amongst. His work bears the same date (1859) as Von Hessling's; and we suppose both to have been published subsequently to the reading of our paper, February 3, 1859.

point the views previously enunciated by Langer, adding to them a description of the histological characters of the vessels intervening between the arterial and venous systems in the *Unio*. It may be considered as beyond a doubt that a system of tubes all but entirely non-lacunar exists in these Lamellibranchiata, carrying their blood from the heart through a systemic, a renal, and a branchial system. No pressure that can in fairness be applied will cause any extravasation of fluid thus injected. Such pressure we have repeatedly applied to *Anodons* very fully distended by injection; and though it be not rare for fluid thrown in by the oviducal outlets to find its way out, as already described, by orifices along the foot, we have never found this to take place with the blood-vascular system.

In making use of the method of injections as a means for showing the independence of the several vascular trees in the Lamellibranchiate mollusks, we have sometimes injected the animal from the oviducal orifice alone, sometimes we have injected the same animal with a differently coloured fluid from its venous or from its arterial system, or from both; in a word, our injections have been either single, double, or triple.

There is no difficulty in causing an injection to enter the body of any large individual of the family Unionidæ from its oviducal orifice; it is especially easy, however, to effect this in the *Unio margaritifera*, as the orifice is not in them, as in most species of the family, covered by the inner lamina of the inner gill, but, together with the orifice of the organ of Bojanus, lies exposed and uncovered in the gill-cavity, and, besides this, is prolonged out in such a manner as to render the introduction of the syringe-pipe a very easy matter.

Experiment 6.—An injection thrown in by this orifice will spread itself over the whole of the viscera contained within the foot, not confining itself by any means to the ovary, but passing on beyond the area occupied by it or the male generative gland, into the exclusively muscular part of the foot, and distributing itself with especial richness along its free edge. That an injection thrown in by this orifice should thus spread itself would go some way towards showing that in the Lamellibranchiate, as in the Brachiopod mollusk, the ducts through which the generative products are extruded lead elsewhere as well as to the generative gland, were it possible to be sure that no transference of the injected fluid had taken place from tubes confessedly in connexion with the generative gland to another system of vessels—that, namely, which carries the blood. That such a transference does not rarely take place in one part of the blood-vascular system, we have already mentioned*;

* Note, p. 454.

necessity for double injections, in which the blood-vascular system was (as has been and will again be described) injected and fully distended throughout the entirety of its own ramifications, before any fluid was thrown into the oviducal orifices, and by still mapping out a tree for itself showed the independence of the system it led to. Single injections, however inferior to double ones, still furnish us with strong arguments for the view we are supporting. A freshwater mussel may have its whole visceral mass perfectly injected, either from the blood-vessels or from the oviducal system; but when thus injected, a practised eye has no difficulty in seeing into which of the two systems the injection has been thrown. The blood-vascular injection is seen to be contained in coarser tubes, and to form a less close network than the aquiferous, which, though confined within fine capillaries, gives, till closely inspected, an appearance almost of uniform diffusion, on account of the closeness of the network it forms.

Secondly, we will give the details of two double injections.

Experiment 7.—A double injection from the venous system and the oviducal in the same *Anodon*. A stiffening size injection of red colour was used for the oviducal or aquiferous system, and the prussian-blue injection, a more easily running fluid, for the venous system, with the following results. The red injection occupies the area corresponding to the generative gland, with coarse as well as with fine twigs, has imparted a faintish blush to the regions occupied by the liver and stomach, but has filled the interior of the exclusively muscular portion of the foot with so close and fine a network as to give it at a distance a uniform red appearance. The blue injection occupies much of the foot-mass in common with and interposed between the red, its larger trunks holding the same position relatively to the larger red trunks as the larger systemic veins do to the larger generative ducts, but it has spread itself into the gills, which the red fluid has not.

Experiment 8.—A similar one to the preceding, but that the blood-vascular system was distended with the fluid used in Experiment 7 for the aquiferous, and *vice versa*. The red fluid was thrown in by the aorta, it filled a large artery running parallel with the cap of the foot, it filled both labial tentacles, and it set, as it stiffened, in bossy masses along the edge of the foot, lastly it returned to the venous sinus and filled it and the organ of Bojanus,—occupying thus the entire systemic and renal-portal vessels. The blue cold injection was thrown in by the orifices through which the generative products are extruded; and we shall see that it, when thus thrown in, disclosed the existence of a system of vessels distinct from those already so

clearly marked out as coextensive with the systemic vessels. It spread itself chiefly over the ovary, but formed a fine plexus along the free edge of the foot beyond the artery described as running parallel with the edge of the foot, and figured as doing so by Langer*.

This experiment must be thought to go a considerable way towards demonstrating the existence of a system of tubes distinct from, however closely apposed to, the blood-vascular system,—this system having been, in this experiment, filled with a rigid mass, and filled with it most thoroughly, as the injection of the organ of Bojanus proves, and yet allowing the tubes injectible from the aquiferous outlet to coexist side by side with it, even though the fluid they contained was so much more easily displaced than the stiffening size injection.

Thirdly, of triple injections.

The readiness with which injections pass from the arterial into the venous system make the triple injections which we have practised of less physiological value than at first sight might appear to be the case; and consequently we will content ourselves with giving the details of one such injection.

Experiment 9.—A large *Anodon* was injected from the venous sinus with a yellow stiffening injection; after this had been done, a blue-coloured fluid, also with size for its basis, was thrown into the aorta; and thirdly, a red injection of the same character was thrown in by the aquiferous opening. The blue fluid thrown into the arterial system drove the yellow fluid before it out of the systemic veins almost entirely, but it did not follow it into the renal-portal system of the organ of Bojanus; this organ and the gills remained richly injected with yellow, to the exclusion of both the other colours; the red fluid, finally, which was thrown in by the aquiferous opening, spread itself in couples with the arterial blue over the entire visceral mass, filling alike the areas of digestive and of reproductive organs, and spreading itself with especial richness over the exclusively muscular part of the foot, which it will be recollected is the part of the animal most preeminently distended and distensible by both natural and artificial means.

Lastly, in a large individual of the freshwater-mussel family in which a stiffening or other injection has been thrown in by the orifice through which the generative products are extruded, a simple lens is sufficient to show that the tubes thus injected have the generative cæca affixed to them laterally, and pass on continuously into parts of the foot in which no generative cæca are lodged. It is most especially in that part of the muscular foot into which no viscera are packed, and which forms a belt of considerable width beyond and bounding the generative mass,

* Denkschriften der K. Akad. Wiss. Wien, Bd. viii. Taf. i. fig. 1.

and yet free from any admixture of its constituent elements (as the microscope will show), that we find the capillary network (shown to be in connexion with the oviducal outlet whilst clear of the terminal cæca) of the gland to attain its maximum development. Now this area is the area also of maximum distention in the distended foot. If in a *Unio* which has been injected from the blood-vascular system and from the oviducal, both with differently-coloured injecting-fluids, a portion of the injected tissue be taken from this area and placed under one of the higher powers of the microscope, the fluid which has been thrown in by the oviducal orifice will be seen to be contained in tubes as well and sharply defined as those of the capillaries which the other injected fluid will show to be in connexion with the blood-vessels.

Whilst the analogy of the Echinodermata and many Annelids does away with any *à priori* improbability which may have seemed to attach to the possession by these mollusks of the system of tubes the existence of which we have been striving to demonstrate, the homology of the Brachiopoda furnishes us with a strong *à priori* presumption in favour of the correctness of our view. On the other hand, we cannot forbear pointing out the great improbability which must attach to a view which supposes a fluid of such morphological and such chemical characters as is the blood of the freshwater mussel to be diluted as it must be diluted on the hypothesis of the blood-vessels being the agents by which the animal voluntarily distends itself often to thrice its undistended bulk. How do the blood-corpuses which we may take from the interior of the animal's heart behave when thus mixed with water under the microscope*? But it is not upon considerations such as these that we would lay most weight, but upon the evidence which injections of the several systems furnish to the unassisted eye, and upon the confirmation of that evidence which microscopic inspection furnishes.

* "Reagentien, wie ein Ueberschuss von Wasser, verdünnte Essigsäure, lösen bei der ersteren Art (Blutkörperchen) den scheinbar festen Inhalt auf, und lassen den Kern, wie die eingeschlossenen Körnchen, deutlich hervortreten. Ihre häufigen Formveränderungen, z. B. die "spiessigen hirschgeweihähnlichen Fortsätze," welche sie treiben, hängen von unvermeidlichen Diffusionsverhältnissen ab, welchen sie bei der grossen Wassermenge gegenüber ihrer verhältnissmässig geringen Anzahl ausgesetzt sind. Während A. Ecker dieselben durch eine Bildung von Vacuolen, in Folge deren Vergrösserung sie einreissen, zu erklären sucht, hält Lieberkühn diese Zellenbildungen für Amöben mit selbständigen contractilen Bewegungen. In innigem Zusammenhang mit diesen Erscheinungen steht das leichte Austreten des Zelleninhalts, welcher bisweilen in hellen und hyalinen Tropfen herumschwimmt, ja nicht selten geht ein Zerfallen desselben in zahlreiche kleine Tröpfchen noch innerhalb der Zellen vor sich, welche dadurch ein maulbeerartiges Ansehen bekommen, ebenso vereinigen die ausgetretenen Sarcodetropfen diese Körperchen zu den oben erwähnten Klümpchen und Flöckchen."—*Von Hessling, loc. cit.* pp. 219, 220.